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# IMF and geomagnetic field : A new feature

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**Abstract** : It is shown that during magnetic storms, besides the decrease of ΔH at low latitudes synchronous with the decrease of ring current index Dst, there are significant changes in *H* associated with the change of IMF-Bz. Large initial phase of the storms is associated with persistent positive Bz continuing after the IP shock. Large positive *ΔH* are observed even during the peak phase of the storms due to sudden large northward turning of IMF-Bz. This seems to be a new feature detected during the nighttime with reduced amplitude at equatorial latitudes.

**Keywords** : Equatorial electrojet, magnetic storms, space weather.

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## 1. Introduction

The association between the Interplanetary magnetic field and geomagnetic activity is well known. Largest Kp or Ap values were found to correspond with the largest southward IMF component by Wilcox *et al* [1] and Patel *et al* [2]. Increasing southward component of IMF increases the reconnection rate at the southward side of the magnetosphere. Nishida [3] showed good correlation between the geomagnetic horizontal component at Huancayo and the Bz component of IMF (measured by IMP 1 satellite).

Rastogi and Chandra [4] first reported the association between the equatorial electrojet and solar wind, based on the spaced receiver ionospheric drift measurements from Thumba near the dip equator. They showed an increase in the westward drift speed during daytime or in the eastward drift speed during nighttime with the increase of the component of Interplanetary magnetic field normal to the ecliptic *i.e.* IMF-Bz (positive when northward). Rastogi and Patel [5] noted that large and quick changes

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of the IMF-Bz from southward to northward direction are associated with the reversal of ionospheric electric field over Jicamarca. Later Rastogi and Kroehl [6] showed that the decrease of $\Delta H$ during DP2 fluctuations at Huancayo and the decrease of ionospheric eastward electric field were associated with similar increases of IMF-Bz component.

Moos [7] identified a well-defined pattern in the so called "X disturbance" in the horizontal component of the geomagnetic field ($H$) at Colaba, Bombay. He found occasional sudden rise of $H$ followed by a rapid decrease lasting for few hours and a slow recovery lasting for 2-3 days. Chapman [8] defined these as "magnetic storms" and named various phases of the magnetic storms as sudden commencement (SC), initial phase (IP), main phase (MP) and recovery phase. Chapman and Ferraro [9–12] suggested that the geomagnetic storms are initiated by the impact on the earth of the ionized solar plasma bubble ejected from the Sun. The decrease of $H$ field was suggested due to the generation of current around the earth due to the polarization of solar plasma. Singer [13] suggested the trapping of charged particles from the Sun after penetrating the earth's geomagnetic field and the creation of the radiation belt and the equatorial ring current.

Suguira and Chapman [14] described the results of 346 magnetic storms at 24 observatories covering the period 1902–1945. They found that no abnormal features of the geomagnetic storms were seen at the equatorial electrojet stations unlike the abnormal intensification of quiet time solar daily variations of $H$ at other stations. Rastogi [15] found that the maximum depression of $H$ during the main phase of the magnetic storm showed a maximum over the magnetic equator larger than expected of the Dst index. Recently Rastogi [16] showed that during magnetic storms, associated with southward IMF-Bz, there are definite enhancements in the decrease of $H$ field at the dayside equatorial stations. Sometimes during the storm period, abnormally large changes in $H$ field are observed associated with large sudden changes of IMF-Bz.

A strong interplanetary shock, with a pressure increase of the order of 30 nPa, reached the earth's magnetosphere at about 0630 UT on 10 November 2000 resulting in a strong sudden commencement of magnetic storm of duration of a day [17]. The solar wind parameters (1) solar wind flow speed, (2) solar wind ion density, (3) Interplanetary magnetic field component Bz as recorded by satellite WIND are reproduced in Figure 1 from the SPIDR (Space Physics Interactive Data Resource) website. The time delay between the arrival of the shock at the satellite and at the earth was on the average of 12 minutes and the variation of this time delay with time is also shown in Figure 1. The time delay is taken into account on the temporal variations of the solar wind parameters. The sudden increase of the solar wind speed and ion density and an abnormally large positive impulse of IMF-Bz are clearly shown in the figure associated with SC. The abnormal features of this storm had been the wild fluctuations of IMF-Bz from about +15 to –15 nT during the period of large wind density. Around

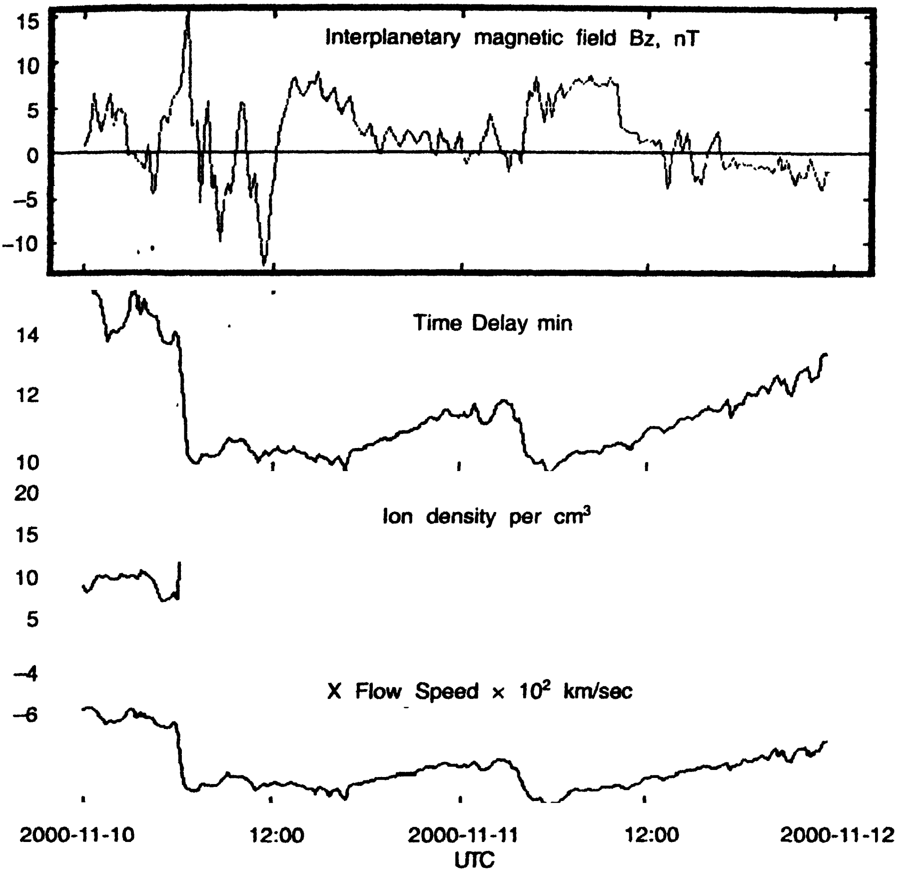


**Figure 1.** Temporal variations of solar wind parameters recorded at satellite WIND on 10 and 11 November 2000.

1100 UT when the solar wind density and speed returned to normal a very large change of IMF-Bz from a value of –12 nT at 1150 UT to a value of +9 nT at 1315 UT was recorded.

SC of 110 nT was recorded at Tirunelveli in India at 0640 UT. The Dst value reached a minimum of –96 nT at 1230 UT. The effects of large geomagnetic storm of November 10, 2000 at low and equatorial stations are presented in the present communication.

## 2. Results

In Figure 2 are shown the variations of hourly mean values on 10 November, 2000 of the parameters (i) density of solar wind, (ii) solar wind velocity, (iii) IMF-Bz, (iv) Dst index and (v) the storm time variations of *H* (H-SqH) at Indian Stations Tirunelveli (TIR), Kodaikanal (KOD), Pondicherry (PON), Alibag (ABG), Ujjain (UJJ) and Sabhawala (SAB). The solar wind density showed a sharp increase from 0530 UT to 0730 UT, thereafter a rapid decrease till 1230 UT and practically remained constant later. The solar wind velocity increased from 500 km/s at 0530 UT to 700 km/s at 0730 UT and

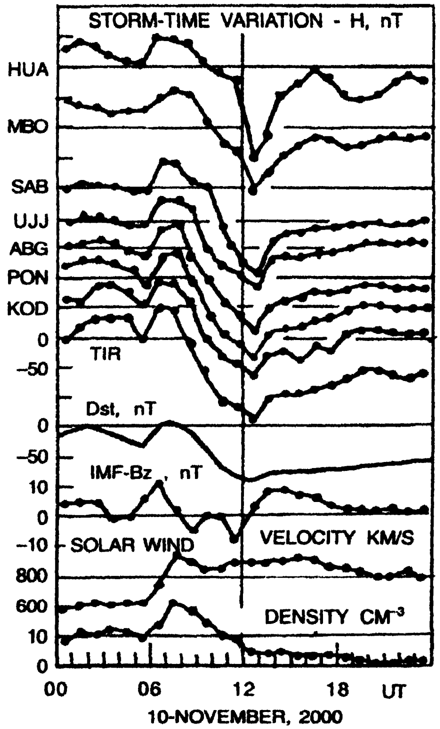


**Figure 2.** Variation of hourly mean values of (i) solar wind density, (ii) solar wind velocity, (iii) IMF-Bz, (iv) Dst index and (v) storm time variations of $H$ (H- SqH) at Indian stations Tirunelveli (TIR), Kodaikanal (KOD), Pondicherry (PON), Alibag (ABG), Ujjain (UJJ) and Sabhawala (SAB) and at Huancayo (HUA) and M'Bour (MBO) on 10 November 2000.

remained constant thereafter. IMF-Bz increased from 0 nT to 10 nT between 0430 and 0630 UT, decreased to –5 nT at 0830 UT. After 1130 UT it showed gradual increase up to 1330 UT. It is to be noted that the storm-time variations of $H$ at any of the stations showed large positive initial phase associated with an increase of Dst index. This was due to the continued compression of the magnetosphere due to the large values of solar wind velocity and density coupled with the positive value of IMF-Bz Storm time variations of $H$ and Dst index started decreasing after 0830 UT with the IMF-Bz turning negative and reached the minimum value at 1300 UT followed by the recovery phase of the storm.

Figure 3 compares the variation of the quarter hourly mean values of IMF-Bz on 10 November, 2000 with the magnetograms at some of the low latitude stations around the world. It can be seen that IMF-Bz had been steadily increasing since 0430 UT to 0630 UT even before the occurrence of SC. The amplitude of SC at Tirunelveli was 110 nT at 0640 UT. During the period 0430 UT to 0630 UT there was a flat minimum of $H$ at these stations. It was only the sudden decrease of IMF at 0630 UT that caused the SC. Another event of importance was a large slow increase of $H$ at Huancayo of about 70 nT at 1130 UT which seems to be associated with the large and steady

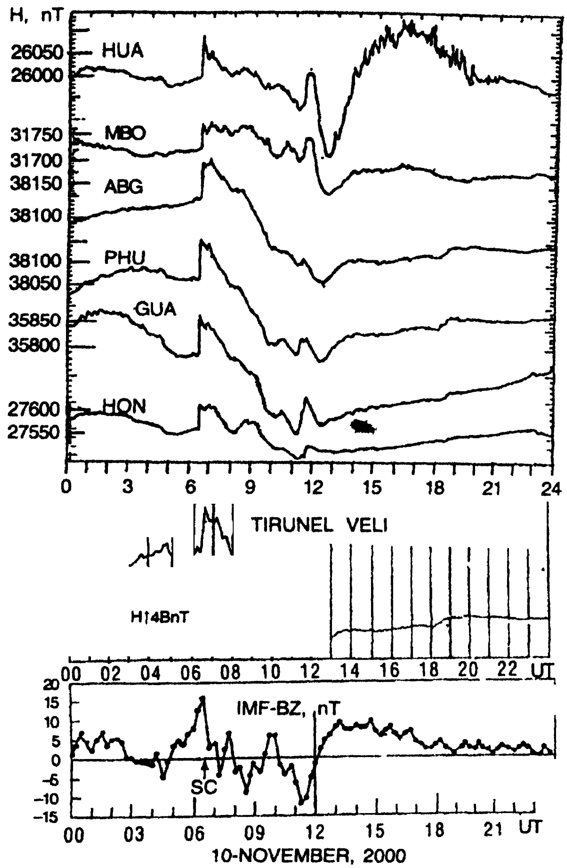


**Figure 3.** Qurter hourly values of IMF-Bz along with the magnetograms of some low latitude stations for 10 November 2000.

increase of IMF-Bz between 1130 and 1330 UT. The local time corresponding to 1130 UT at these stations are 0630 LT at Huancayo (HUA), 1022 LT at MBO, 1618 LT at Alibag (ABG), 1834 LT at PHU, 2106 LT at Guam (GUA) and 2002 LT at Honolulu (HON). This impulse can be seen at other stations but had been very weak at Indian stations Tirunelveli and Alibag, which were in the local evening sector (1618 LT at Alibag). There were no suitable longitudinal distribution of equatorial electrojet stations and so the local time effect of such events cannot be investigated.

Prof. K Yumuto of the Kyushu University, Japan had organized geomagnetic observatories under the Circum-pan Pacific Magnetometer Network. The daily maps of X and Y fields at these stations are available in their website. Figure 4 shows the recast stack plots of the X component magnetograms at some of the stations on a uniform sensitivity scale. The stations are distributed in the geographic longitude between 114° E to 150° E cover dip of 59° N to 67° S. The SC at 0630 UT and a positive pulse around 1200 UT on 10 November 2000 are clearly recorded at all stations (Table 1). The first impulse at 0630 UT was by the IP shock when the solar

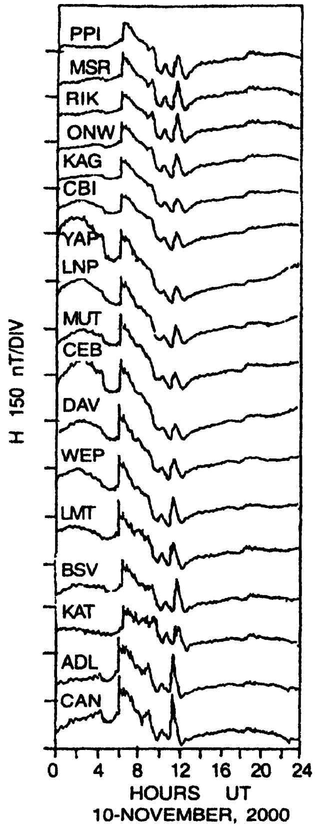


**Figure 4.** The X component magnetograms at a number of stations covering dip of 59° N to 67° S for 10 November 2000 in the longitude region of 114°E–150°E .

**Table 1.** Dip and geographic longitudes of the stations shown in Figure 4

| Station name | Station code | Dip °N | Geog. longitude °E |
|---|---|---|---|
| Popov Island | PPI | 59 | 131.7 |
| Moshiri | MSR | 58 | 142 3 |
| Rikubetsu | RIK | 57 | 143.8 |
| Onagawa | ONW | 52 | 141.5 |
| Kagoshima | KAG | 46 | 130.7 |
| Chichijima | CBI | 36 | 142.2 |
| Lunping | LNP | 36 | 121.2 |
| Muntinlupa | MUT | 16 | 121.0 |
| Yap | YAP | 6 | 138.5 |
| Cebu | CEB | 3 | 123.9 |
| Davao | DAV | –1 | 125.6 |
| Weipa | WEP | –39 | 141.9 |
| Learmonth | LMT | –56 | 114.1 |
| Birdsville | BSV | –57 | 139.2 |
| Katanning | KAT | –68 | 117.6 |
| Adelaide | ADL | –66 | 138.4 |
| Canberra | CAN | –67 | 149.4 |

wind shock struck the magnetosphere while the second impulse at 1130 UT was due to the abnormal large change of IMF-Bz from a value of –12 nT at 1115 UT to a value of +9 nT at 1350 UT without any significant change of solar wind density or speed. The local time corresponding to the second impulse around 1130 UT for these stations was between 1900 LT and 2130 LT. It is interesting to note that the amplitude of the pulse was minimum at equatorial stations and steadily increased with increasing dip latitude north or south.

## 3. Conclusion

There have been numerous studies related to the geomagnetic storm effects in the density, composition and dynamics of the sub-auroral, middle and low latitude ionosphere and thermosphere *e.g.* Kelley [18], Fuller-Rowell *et al* [19], Basu *et al* [20], Fejer [21]. Prompt penetration and disturbance dynamo electric fields, though of smaller magnitude, are the important sources of low latitude ionospheric electrodynamic disturbances. Sharp electric field perturbations with time scales typically shorter than about an hour are due mostly to the prompt penetration of solar wind/magnetospheric electric fields to middle, low and equatorial latitudes [21 and references therein]. Quasi-period (DP2) magnetic field fluctuations with time scale of about half an hour to several hours at high latitudes and in the dayside of magnetic equator are signatures of convection electric fields controlled by IMF-Bz [3]. Slower varying electric field disturbances with time scales of few hours to tens of hours are identified as ionospheric disturbance dynamo electric fields caused by enhanced energy deposition in to the auroral ionosphere *e.g.* Blanc and Richmond [22].

The effects of magnetic storm at low latitude stations are not entirely due to the overhead equatorial ring current but are modified by the change of solar wind parameters (velocity, density and IMF-Bz). A new feature of large positive impulse in *H* during the nighttime associated with large steady change of IMF-Bz with reduced amplitude at lower latitudes is detected.

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